2-1964

Phosphorus and Potassium Fertilization

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LETIN 376 FEBRUARY 1964

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in Crop Rotations

by
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COVER PHOTO: The availability of the phosphorus is important. The tall corn on the left was fertilized with superphosphate; the short corn on the right was fertilized with rock phosphate.

Summary and Conclusions

Yields of corn, wheat, and red clover in a 3-year rotation are summarized on three major soil series at three locations for periods ranging from 10 to 13 years.

- Phosphorus was the fertilizer element under study throughout the entire course of these experiments. In the beginning three different sources of phosphorus—concentrated superphosphate (CSP), fused tricalcium phosphate (FTP), and rock phosphate (ROCK) —were compared, usually at two rates. Later some phosphorus treatments were dropped, at which time the experiment was changed to a study of rates of phosphorus (CSP) and potassium. One ROCK treatment was continued throughout.
- Significant yield responses to applied phosphorus were obtained with all three crops on all three soils. The performance of FTP in most cases compared favorably with that of CSP, but the performance of ROCK was greatly inferior, even where ROCK was applied at a rate three times that of the "available" phosphates. Assigning a value of 100 for the yields obtained with CSP, the average relative yield obtained with FTP on all crops at all locations was 95, while the relative yield obtained with ROCK at the higher rate was 76. ROCK was least satisfactory on wheat of the three crops studied. Of the three soils ROCK's poorest performance was on a virgin Hartsells loam, a soil derived from sandstone on the Cumberland Plateau.
- In the rates studies of phosphorus and potassium, which were conducted in the latter half of these experiments, 40 pounds of P_2O_5 appeared to be ample for corn, except an increase of about 5 bushels was obtained with an 80-pound P_2O_5 application on Cumberland loam at Knoxville. Wheat continued to respond to phosphorus up to the last increment (80 pounds of P_2O_5 per acre), although the greatest response was to the first increment (40 pounds of P_2O_5).
- Applications of potassium had little effect on yields on the Cumberland soil, but became of major importance on corn and red clover on a Dickson silt loam at Springfield. On this soil corn and wheat responded to applications as high as 90 pounds of K_2O per acre. Potassium was not under study on the Hartsells soil.
- Red clover was not fertilized directly. Difficulty was experienced in getting stands at Knoxville and Springfield; in some years the crop was a failure.

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Phosphorus and Potassium Fertilization in Crop Rotations

by

O. H. Long, J. A. Odom, and L. M. Safley[1]

INTRODUCTION

A 3-year rotation of corn, wheat and red clover was conducted at each of three locations—Knoxville, Crossville and Springfield—beginning in the fall of 1948 and extending over periods ranging from 10 to 13 years. When the experiments were started the fertilizer element under study was phosphorus and different phosphate materials were applied, most of them at more than one rate. About midway in the course of the experiments some of the phosphates were discontinued, at which time potassium was introduced as a fertilizer variable.

The experiments were so arranged that all three crops of the rotation grew every year. This was accomplished by providing three blocks or ranges of land. Corn would be on one block, wheat on another, and red clover on still another, with the crops following each other in the order: corn-wheat-red clover. This order was repeated until the experiments were concluded.

EXPERIMENT AT KNOXVILLE—FIRST PHASE

The rotation on the University (Blount County) Farm at Knoxville was located on a Cumberland soil, the surface of which is largely loam in texture but includes some clay loam (about 20% of the area). The experiment originally contained seven phosphorus treatments, each replicated six times. Soil samples taken before the experiment was started indicated a pH in the range of 6.5 to 6.9, low to very low in phosphorus and medium in potassium (155 pounds K per acre).

Concentrated superphosphate (CSP), rock phosphate (ROCK), and fused tricalcium phosphate (FTP) were the three phosphorus

[1] Professor of Agronomy, Knoxville, and Superintendents of Plateau Experiment Station, Crossville, and Highland Rim Experiment Station, Springfield, respectively. D. H. Latham was in charge of the rotation at Springfield during the period 1948-1951.

sources under test, each applied at two rates. CSP and FTP were applied at rates of 60 and 120 pounds of P_2O_5 (26 and 53 pounds of P) per acre while ROCK was applied at rates of 120 and 360 pounds P_2O_5 (53 and 158 pounds of P) for the 3-year period.[2] Where CSP and FTP were used the application was divided, one-third being applied to the corn crop and two-thirds to the wheat crop. Red clover, which was usually over-seeded on the wheat in late winter, was not fertilized directly. ROCK was applied broadcast once in the rotation cycle, before wheat was seeded.

Nitrogen and potassium were applied at uniform rates—65 pounds of N per acre on corn, 35 pounds of N on wheat; and 50 pounds of K_2O (42 pounds of K) per acre to both the corn and wheat crops.[2] These materials were applied in the row for corn and broadcast for wheat.

The yields obtained with CSP and ROCK are shown in Table 1; the yields obtained with FTP will be discussed later.

Table 1.—Yields of corn, wheat, and red clover obtained with concentrated superphosphate (CSP) and rock phosphate (ROCK) in a 3-year rotation on Cumberland loam. (First phase, 1949-1955)

(Average of 6 replications)

Source of phosphorus and pounds per acre of P_2O_5 for 3-year period	Year							6- or 7-year average
	1949	1950	1951	1952	1953	1954	1955	
				CORN (bushels per acre)				
CSP, 60	77.7	94.5	78.7	28.2	66.0	52.3	....	66.2
CSP, 120	82.0	108.0	88.6	34.1	68.6	54.5	....	72.6
ROCK, 120	70.4	93.1	68.5	24.6	66.4	42.5	....	60.9
ROCK, 360	76.9	101.9	79.2	33.8	68.8	49.1	....	68.3
L. S. D. (5%)	10.7	8.8	16.9	8.1	N.S.	N.S.	....	....
				WHEAT (bushels per acre)				
CSP, 60	31.8	39.1	30.7	35.2	44.8	32.5	....	35.7
CSP, 120	30.2	43.8	35.1	39.8	48.2	40.2	....	39.6
ROCK, 120	29.6	29.8	21.6	22.1	30.6	24.0	....	26.3
ROCK, 360	30.5	30.8	23.6	27.9	38.4	28.6	....	30.0
L. S. D. (5%)	N.S.	3.3	5.2	2.7	3.3	3.9	....	....
				RED CLOVER HAY (tons per acre)				
CSP, 60	0.98	3.76	1.96	0.35	0.43	0.50	0.28	1.18
CSP, 120	1.11	3.83	2.04	0.39	0.61	1.06	0.50	1.36
ROCK, 120	1.13	2.95	1.48	0.38	0.24	0.45	0.63	1.04
ROCK, 360	1.08	3.11	1.85	0.51	0.33	1.19	0.64	1.24
L. S. D. (5%)	N.S.	N.D.*	N.D.*	0.13	N.S.	0.40	N.S.	....

*N.D. = Not determined. Red clover yields include one cutting on the area where wheat was harvested earlier that same year.

Corn yields for the 6-year period, 1949-1954, averaged the lowest (60.9 bushels) where ROCK was applied at the 120-pound P_2O_5 rate and the highest (72.6 bushels) where CSP was applied at the 120-pound P_2O_5 rate. ROCK at the 360-pound P_2O_5 rate produced yields averaging slightly higher than those produced with CSP at the 60-pound P_2O_5 rate. With both phosphorus sources there was an increase in yield with the higher rate of application; CSP produced 6.4 bushels and ROCK 7.4 bushels more corn at the higher rate than at the lower rate. Corn yields were highest in 1950 and lowest in 1952; the average yield of almost 100 bushels in 1950 was more than three times the average yield in 1952, a very dry year.

As with corn, wheat yields were also lowest with the ROCK treatment at the 120-pound P_2O_5 rate; this treatment averaged 26.3 bushels per acre. In fact, the higher rate of ROCK was inferior to the lower rate of CSP. The highest yield (39.6 bushels) was obtained with CSP at the 120-pound P_2O_5 rate. Wheat yields did not fluctuate as widely as those of corn. The highest yield (averaging 40.5 bushels) was obtained in 1953 and the lowest (averaging 27.8 bushels) in 1951—a spread of less than 13 bushels.

Red clover yields were fairly satisfactory in the early years of the rotation, but declined in later years. This decline may be attributed in part to a build-up in the disease-causing organisms that attack red clover, but the more likely explanation was the competition by the wheat in which the red clover was seeded. In later years, in an attempt to avoid this competition and to get better stands of red clover, seedings were made on seedbeds prepared after the wheat was harvested, but stands and growth continued to be unsatisfactory. As a 7-year average the maximum yield of red clover hay (1.36 tons) was obtained with CSP at the higher rate. The yield obtained with ROCK at the higher rate (1.24 tons) was a close second. ROCK at the lower rate produced the lowest yield (1.04 tons).

FUSED TRICALCIUM PHOSPHATE.—As mentioned earlier, fused tricalcium phosphate (FTP) was used in the first phase of this experiment. Two particle sizes were tested: one was rather coarse (ground to pass through a 10-mesh screen) while the other was finer (ground to pass through a 40-mesh screen). The coarser material was applied at two rates. The yields obtained with the FTP treatments were as follows:

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[2] The customary practice is to express phosphorus fertilization in terms of P_2O_5 and potassium fertilization in terms of K_2O. For those who prefer to express these two plant nutrients in terms of the elements phosphorus (P) and potassium (K), any rate of P_2O_5 can be converted to P by multiplying that rate by 0.44; any rate of K_2O can be converted to K by multiplying that rate by 0.83.

Particle size and pounds of P_2O_5 applied per 3-yr. period	6- or 7-year average Corn Bu./A	Wheat Bu./A	Red clover hay Tons/A
FTP, –10 mesh, 60	66.8	31.9	1.31
FTP, –10 mesh, 120	71.0	34.5	1.49
FTP, –40 mesh, 60	69.3	32.0	1.10

Comparing these yields with those obtained with CSP (Table 1), it will be seen that FTP compared favorably with CSP on corn but was slightly inferior on wheat and red clover.

EXPERIMENT AT KNOXVILLE—SECOND PHASE

Beginning with the wheat crop in 1954, a change was made in the fertilizer treatments on the rotation at Knoxville. The three fused tricalcium phosphate treatments and rock phosphate at the lower rate (120 pounds of P_2O_5) were discontinued. Their discontinuance provided space which permitted a study of CSP at more than two rates as well as potassium at more than one rate. At the same time the number of replications of each treatment was reduced from 6 to 3.

CORN.—In Table 2 the yields of corn with the various fertilizer treatments for the 7-year period, 1955-1961, are presented. This table also shows the former fertilizer treatments.

Summarizing treatments 1 to 12, corn yields for the various rates of phosphorus fertilization across all rates of potassium are as follows:

Phosphorus rate (Pounds of P_2O_5 per acre)	Bushels of corn per acre (7-year average, 1955-1961)
0	57.1
40	70.1
60	70.8
80	75.0

The yields for the various rates of potassium fertilization across all rates of phosphorus are as follows:

Potassium rate (Pounds of K_2O per acre)	Bushels of corn per acre (7-year average, 1955-1961)
0	65.9
30	69.1
60	69.7

From these data it can be concluded that on this soil phosphorus fertilization was of much more importance than potassium fertilization. Where no phosphorus was applied corn yields averaged 57.1 bushels, but they averaged 70.1 bushels where phosphorus was applied at the 40-pound P_2O_5 rate—an increase of 13 bushels. A further increase of about 5 bushels was obtained at the 80-pound P_2O_5 rate. The increase from potassium was only 3 or 4 bushels.

Table 2.—Yields of corn obtained with various phosphorus-potassium treatments in a 3-year rotation on Cumberland loam (Second phase, 1955-1961) (Average 3 replications)

Tmt. No.	Former treatment (Period 1948-1954)	Fertilization* (lb./acre)		Year							7-year av.
		P_2O_5	K_2O	1955	1956	1957	1958	1959	1960	1961	
				Bushels per acre							
1	Rock, 120	0	0	71.2	63.3	31.4	57.9	70.8	50.8	58.1	57.6
2	Rock, 120	0	30	64.4	61.9	29.8	54.7	68.1	53.2	50.1	54.6
3	FTP, -10 mesh, 60	0	60	70.6	42.0	44.6	60.9	63.5	71.5	59.8	59.0
4	FTP, -10 mesh, 60	40	0	78.7	78.2	47.3	71.4	79.5	76.6	69.4	71.6
5	CSP, 120	40	30	77.2	62.1	40.2	80.4	74.5	68.3	86.5	69.9
6	CSP, 60	40	60	76.6	63.6	41.8	74.8	69.3	80.9	74.5	68.8
7	FTP, -40 mesh, 60	60	0	83.3	63.1	38.6	67.4	69.0	59.1	74.2	65.0
8	CSP, 120	60	30	87.5	65.1	56.7	86.7	77.6	83.1	77.0	76.2
9	CSP, 60	60	60	80.3	67.0	41.1	80.2	73.7	72.9	83.6	71.3
10	FTP, -40 mesh, 60	80	0	84.7	72.1	46.2	71.8	73.3	70.9	67.6	69.5
11	FTP, -10 mesh, 120	80	30	86.8	58.9	49.8	94.0	66.3	86.7	87.9	75.8
12	FTP, -10 mesh, 120	80	60	83.9	81.2	58.1	80.6	81.1	90.1	83.4	79.8
13	Rock, 360	360[1]	60	80.6	60.4	55.0	81.7	69.5	83.3	91.0	74.5
14	Rock, 360	**360[1]	60	81.2	74.4	35.7	89.9	82.7	66.4	94.1	74.9

* All treatments fertilized with neutralized ammonium nitrate at rate 65 pounds N per acre.
**ROCK supplemented with CSP at rate 20 pounds P_2O_5 per acre.
[1] ROCK was applied only once in the rotation—before seeding wheat.

Rock phosphate (treatment 13) compared very favorably with concentrated superphosphate in this the second phase of this experiment. Its performance was not improved by supplementing it with small amounts of CSP (treatment 14). ROCK with or without CSP averaged about 75 bushels of corn per acre, which was about the yield obtained with CSP at the 80-pound P_2O_5 rate. The ROCK treatments could not have been affected by a different phosphate in the first phase, as these treatments remained unchanged throughout the entire course (13 years) of this experiment.

WHEAT.—Yields of wheat are presented in Table 3 in a manner similar to that for corn. Summarizing treatments 1 to 12, wheat yields for the various rates of phosphorus fertilization across all rates of potassium are as follows:

Phosphorus rate (Pounds of P_2O_5 per acre)	Bushels of wheat per acre (7-year average, 1955-1961)
0	22.3
40	36.1
60	37.4
80	39.2

The yields for the various rates of potassium fertilization across all rates of phosphorus are as follows:

Potassium rate (Pounds of K_2O per acre)	Bushels of wheat per acre (7-year average, 1955-1961)
0	32.8
30	34.4
60	34.1

Wheat, like corn, responded markedly to phosphorus fertilization. Where no phosphorus was applied the average yield was 22.3 bushels per acre. At the 80-pound P_2O_5 rate the yield was 39.2 bushels—almost double the yield of the no-phosphorus treatment. Most of this increase occurred with the first increment of phosphorus. Potassium fertilization was of little effect on wheat yields; the increase from applied potassium was about 1½ bushels.

RED CLOVER.—Yields of red clover hay are presented in Table 4. The disease problem, which has already been mentioned, became more severe in the second phase. In 1959 and 1960 the stand was so poor that yields were not measured. Most of the red clover seedings in the second phase were made on prepared seedbeds. Summarizing treatments 1 to 12, hay yields for the various rates of phosphorus fertilization across all rates of potassium are as follows:

Phosphorus rate (Pounds of P_2O_5 per acre)	Tons of red clover hay (6-year average, 1956-1961)
0	0.57
40	0.84
60	0.85
80	1.08

Table 3.—Yields of wheat obtained with various phosphorus-potassium treatments in a 3-year rotation on Cumberland loam (Second phase, 1955-1961) (Average 3 replications)

Tmt. No.	Former treatment (Period 1948-1954)	Fertilization* (lb./acre)		Year							7-yr. av.
		P_2O_5	K_2O	1955	1956	1957	1958	1959	1960	1961	
				Bushels per acre							
1	Rock, 120	0	0	17.8	47.6	18.6	23.9	15.6	14.4	28.1	23.7
2	Rock, 120	0	30	18.1	40.3	15.6	20.9	11.0	15.4	23.7	20.7
3	FTP, -10 mesh, 60	0	60	24.7	40.5	12.6	24.9	14.4	12.2	28.7	22.6
4	FTP, -10 mesh, 60	40	0	40.6	55.0	23.5	33.3	32.1	22.2	40.2	35.3
5	CSP, 120	40	30	39.3	53.3	31.0	36.2	44.1	19.1	44.5	38.2
6	CSP, 60	40	60	41.3	49.3	27.0	32.8	37.5	18.3	37.9	34.9
7	FTP, -40 mesh, 60	60	0	41.6	47.8	26.0	35.8	37.4	20.9	40.1	35.7
8	CSP, 120	60	30	38.8	52.2	28.9	31.4	45.3	25.6	36.4	36.9
9	CSP, 60	60	60	43.6	53.0	29.2	33.4	43.3	25.4	49.4	39.6
10	FTP, -40 mesh, 60	80	0	41.2	54.0	28.6	33.1	38.5	23.5	36.6	36.5
11	FTP, -10 mesh, 120	80	30	47.9	54.0	30.3	37.1	49.5	24.4	50.0	41.9
12	FTP, -10 mesh, 120	80	60	41.6	53.0	31.1	35.8	42.9	27.9	42.0	39.2
13	Rock, 360	360[1]	60	41.9	50.0	26.9	32.6	36.8	19.4	43.4	35.9
14	Rock, 360	**360[1]	60	28.2	47.6	25.7	31.3	39.0	28.8	42.1	34.7

* All treatments fertilized with neutralized ammonium nitrate at rate 35 pounds of N per acre.

** ROCK supplemented with CSP at rate 20 pounds P_2O_5 per acre.

[1] ROCK was applied only once in the rotation—before seeding wheat.

Table 4.—Yields of red clover obtained with various phosphorus-potassium rates applied to corn and wheat in a 3-year rotation on Cumberland loam (Second phase, 1956-1961)
(Average 3 replications)

Tmt. No.	Former treatment (Period 1948-1955)	Fertilization* (lb./acre)		Year						6-year av.
		P_2O_5	K_2O	1956	1957	1958	1959	1960	1961	
				Tons hay per acre						
1	Rock, 120	0	0	1.05	0.89	0.85			0.73	0.59
2	Rock, 120	0	30	0.91	0.82	0.90			0.46	0.52
3	FTP, -10 mesh, 60	0	60	1.98	1.04	0.32			0.25	0.60
4	FTP, -10 mesh, 60	40	0	2.03	1.64	1.36			0.78	0.97
5	CSP, 120	40	30	1.79	1.80	0.93			0.34	0.81
6	CSP, 60	40	60	2.09	1.25	0.56	Crop failed due to disease	Crop failed due to disease	0.52	0.74
7	FTP, -40 mesh, 60	60	0	1.72	1.56	0.78			0.71	0.80
8	CSP, 120	60	30	2.03	1.98	1.50			0.36	0.98
9	CSP, 60	60	60	1.44	1.56	1.07			0.49	0.76
10	FTP, -40 mesh, 60	80	0	1.88	1.40	1.50			0.51	0.88
11	FTP, -10 mesh, 120	80	30	2.72	2.42	0.81			0.55	1.08
12	FTP, -10 mesh, 120	80	60	2.78	2.28	1.77			0.86	1.28
13	Rock, 360	360[1]	60	3.51	2.23	0.87			0.57	1.20
14	Rock, 360	**360[1]	60	1.14	1.87	1.47			0.70	0.86

* Applied to the previous corn crop and repeated on the wheat.

**ROCK supplemented with CSP at rate 20 pounds of P_2O_5 to the corn crop and 20 pounds to the wheat crop.

[1] ROCK was applied only once in the rotation—before seeding wheat.

The yields for the various rates of potassium fertilization across all rates of phosphorus are as follows:

Potassium rate (Pounds of K_2O per acre)	Tons of red clover hay (6-year average, 1956-1961)
0	0.81
30	0.85
60	0.85

As was the case with corn and wheat, red clover responded mainly to phosphorus fertilization. Average yields were 0.57 ton of hay on the no-phosphorus treatment and 1.08 tons at the highest rate of phosphorus fertilization. The 2 years of failure are included in these averages. There was little or no response to potassium fertilization at these low yield levels.

EXPERIMENT AT PLATEAU EXPERIMENT STATION, CROSSVILLE

The rotation at the Plateau Experiment Station, Crossville, was located on a virgin Hartsells loam soil, the area having been cleared of trees the winter before the experiment was started in the spring of 1948. As far as is known it had never been limed or fertilized. The Hartsells soil is derived from sandstone.

The area was limed in early spring 1948 using two sources of agricultural lime—Crab Orchard (calcitic) and Mascot (dolomitic) limestone. The calcitic limestone was applied at two rates—½ ton and 2 tons per acre; the dolomitic limestone was applied only at the 2-ton rate.

The experimental design was similar to that at Knoxville in that three blocks of land were used—one for each crop. In the first 5 years of the rotation winter oats was the small grain crop. (Spring oats was seeded for hay in 1948.) Wheat was substituted for winter oats beginning in the fall of 1952 because the latter frequently froze out, due in part to late seedings (after corn harvest).

CSP, FTP and ROCK were the three sources of phosphorus used in this rotation. CSP was applied at two rates: 60 pounds and 120 pounds of P_2O_5 per acre per 3-year cycle. FTP was applied at one rate: 120 pounds of P_2O_5. ROCK was applied at two rates: 120 pounds and 360 pounds of P_2O_5. Some increases in rate of application were made in 1954, which will be indicated later. With CSP and FTP the application was divided, one-third of the total amount being applied in the row for corn and two-thirds broadcast for wheat. ROCK was applied broadcast only once in the 3-year cycle which, after the initial application, was just ahead of the small grain seeding.

A split-plot experimental design was used with the phosphorus treatments as the main plots and the limestone treatments as the sub-plots.

In all phosphorus treatments nitrogen and potassium were applied to the corn and wheat crops—in the row for corn and broadcast for wheat. The rates were 65 pounds of N and 50 pounds of K_2O per acre for corn, and 35 pounds of N and 50 pounds of K_2O for wheat. Beginning with the 1955 seeding of wheat, the nitrogen fertilization was increased to 60 pounds of N on this crop (35 pounds at seeding and 25 pounds as a spring topdressing).

Soil tests made before the experiment was started were lost but samples taken in the summer of 1949, about 15 months after the experiment was started, tested as follows: pH = 5.3 to 5.4 where limed at the 2-ton rate and pH = 4.9 where limed at the ½-ton rate. Phosphorus was low (6 pounds P per acre) where CSP was applied at the lower rate, and potassium was medium (175 pounds K per acre). Tests run on a complete set of soil samples collected from one range in 1955 (6 years later) indicated no material change in soil reaction, the pH ranging from 5.1 to 5.3 for the three lime treatments.

Yields of corn, wheat, and red clover for the period 1948-1957 are shown in Table 5.

Before discussing the performance of the various crops it should be pointed out that these yields do not represent the maximum potential of this soil. Phosphorus fertilization in particular was considerably less than optimum. On numerous occasions phosphorus deficiency symptoms were observed in the growing crops—corn, for example—particularly at the lower rates of phosphorus fertilization. Therefore, crop performance should be viewed from the standpoint of what the experiment was designed to do, namely, to evaluate different sources of phosphorus at moderate rates of application.

CORN.—As a 9-year average corn yields ranged from a high of 50.6 bushels per acre where CSP was applied at the 120-pound-P_2O_5 rate to a low of 28.6 bushels where ROCK was applied at the same rate. The difference in corn growth on these two treatments is illustrated on the front cover. Note that the performance with ROCK at the lower rate (Table 5) was consistently inferior to that at the higher rate until 1954, when the former treatment was supplemented with CSP. From then on the ROCK-CSP treatment outyielded the ROCK treatment. The yield increased about eight bushels where the rate of CSP was doubled. FTP compared favorably with CSP at equal rates. These yields are averages of all lime treatments and their ranking as shown here remained unchanged from one lime treatment to

Table 3.—Yields of corn, wheat and red clover obtained with various phosphorus treatments in a 3-year rotation on Hartsells loam, 1948-1957
(Yields are averages of 3 lime treatments—3 replications of each lime treatment)

Source of phosphorus and pounds per acre of P_2O_5 applied for 3-year period*	Year									av.
	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	
CORN (bushels per acre)											
CSP, 60	36.7	36.5	38.4	47.9	19.9	60.2	20.0	60.0	63.0	....	42.5
CSP, 120	47.1	42.9	49.2	56.2	26.9	70.7	22.2	70.6	69.7	....	50.6
ROCK, 120	9.1	16.9	17.4	26.2	12.0	39.3	19.3	54.7	62.7	....	28.6
ROCK, 360	12.0	26.6	26.5	29.3	17.4	52.4	16.4	53.7	58.7	....	32.6
FTP, -10 mesh, 120	30.8	43.8	44.2	56.0	20.9	61.7	22.6	63.9	60.7	....	44.9
L. S. D. (5%)	7.2	6.0	3.8	7.1	3.8	14.5	2.6	4.6	2.7	....	....
WHEAT (bushels per acre)	[1]	[2]	[2]	[3]	[2]						
CSP, 60	0.44	18.8	17.7	0.48	13.9	18.4	12.7	13.1	14.1	17.2	15.1
CSP, 120	0.52	27.3	18.7	0.61	18.1	26.9	18.1	17.9	20.1	22.1	21.0
ROCK, 120	0.00	7.7	7.0	0.37	0.08	5.8	3.0	12.1	15.3	17.8	10.8
ROCK, 360	0.00	10.5	9.2	0.42	1.3	9.7	6.7	5.1	9.5	10.3	8.2
FTP, -10 mesh, 120	0.20	27.3	19.7	0.57	14.9	26.6	14.6	14.0	22.0	19.1	19.3
L. S. D. (5%)	0.07	5.4	3.5	0.16	5.1	2.4	2.1	4.0	5.6	1.9	....
RED CLOVER HAY (tons per acre)											
CSP, 60	0.30	2.08	2.48	0.80	0.80	2.01	0.79	1.57	1.02	1.07	1.29
CSP, 120	0.43	2.68	3.69	0.99	1.12	2.97	1.18	1.98	1.37	1.45	1.80
ROCK, 120	0.16	1.79	1.79	0.76	0.55	1.50	0.62	1.70	1.09	1.25	1.12
ROCK, 360	0.28	1.99	2.57	0.99	0.89	2.25	1.21	2.20	1.38	1.43	1.52
FTP, -10 mesh, 120	0.41	2.73	3.68	1.07	1.07	3.05	1.26	2.06	1.28	1.59	1.82
L. S. D. (5%)	0.10	N.D.	N.D.	N.D.	0.26	0.48	0.16	0.27	N.S.	0.22	....

* Beginning with corn crop in 1954 rate of application of P_2O_5 was increased 50% in all treatments; in addition ROCK at the lower rate was supplemented with CSP at the rate of 30 pounds of P_2O_5 on both the corn and wheat crops.

[1] Spring oat hay (tons per acre). [2] Winter oats (bushels per acre). [3] Winter oat hay (tons per acre).

another. All phosphorus treatments averaged 41.2 bushels with calcitic limestone at the 2-ton rate, 39.8 bushels with dolomitic limestone at the 2-ton rate, and 38.5 bushels with calcitic limestone at the ½-ton rate.

WHEAT.—As a 5-year average, wheat yields ranged from a high of 21.0 bushels per acre with CSP at the 120-pound P_2O_5 rate to a low of 8.2 bushels with ROCK at the same rate. As with corn, where ROCK was supplemented with CSP beginning with the 1955 crop, the ROCK-CSP treatment was superior to ROCK alone. There was about a 6-bushel increase in yield as a result of doubling the rate of CSP. FTP was slightly inferior to CSP.

Average yields for all phosphorus treatments was 15.4 bushels for both liming materials at the 2-ton rate and 13.9 bushels at the ½-ton rate of calcitic limestone. As was the case with corn, wheat yields maintained their same relative position with the different phosphorus treatments on the three lime treatments.

Yields of oats, grown in the first 5 years of the experiment, are shown as a matter of record but are not included in the average. Spring oats failed to produce a harvestable yield of hay on the two ROCK treatments in the first year of the experiment.

RED CLOVER.—As a 10-year average red clover hay yields ranged from a high of 1.80 tons of hay per acre for the 120-pound P_2O_5 rate of CSP to a low of 1.12 tons for ROCK at the same rate. Yields were increased approximately ½-ton by doubling the rate of CSP. The performance of ROCK was relatively the best on the red clover crop of the three crops under test, but even here CSP at only one-third the total P_2O_5 rate produced 0.28 ton (18%) more hay.

Average yields for all phosphorus treatments was 1.61 tons for dolomitic limestone at the 2-ton rate and 1.53 and 1.39 tons for calcitic limestone at the 2- and ½-ton rates, respectively. The relative performance of the different phosphorus treatments was essentially the same on the three lime treatments.

In some years a cutting of red clover was obtained in the fall from the area where the small grain had been harvested earlier that year. This occurred in 1949, 1950, 1953, and 1955. This cutting, representing 20% to 35% of the total production, was added to the cuttings of red clover made on the area that had produced a small grain crop the previous year. This combined production from the two areas partly explains the higher yields obtained in these four years.

MAGNESIUM DEFICIENCY IN CORN.—Magnesium deficiency symptoms were observed on corn in the calcitic limestone treatments in 1948, the first year of the experiment. These symptoms—a distinct parallel white striping of the leaves and stunted growth of the entire plant—were very pronounced where calcitic limestone had been applied at the ½-ton rate but were rarely evident at the 2-ton rate.

Figure 1. Influence of rate of liming on corn growth. Corn at left limed at rate of 2 tons per acre; at right, limed at ½-ton rate. Calcitic limestone used in both treatments.

There was no evidence of this deficiency where dolomitic limestone had been applied. A photograph of the corn, made on July 13, is shown in Figure 1. Despite the difference in growth at this time, grain yields at harvest were about the same on all three lime treatments. Had this deficiency been more pronounced at the 2-ton rate of calcitic limestone, it could be explained as an imbalance of calcium with magnesium; but since such was not the case, the observation is recorded without explanation. Magnesium deficiency with dolomitic limestone would not be expected since this liming material contains a considerable amount of magnesium.

No magnesium deficiencies were observed in later years.

EXPERIMENT AT HIGHLAND RIM EXPERIMENT STATION, SPRINGFIELD—FIRST PHASE

The rotation at Springfield, like that at Knoxville, was started in 1948 as a phosphorus comparison study. It originally contained 8 phosphorus treatments under limed (2 tons per acre of ground limestone) and unlimed conditions, each treatment being replicated three times. In late summer of 1951 the entire area was limed, reapplying ground limestone at the rate of 2 tons per acre on the part that had previously been limed and applying 3 tons per acre on the unlimed part. A second change was made beginning with the seeding of wheat in 1954, when some of the phosphorus treatments were discontinued. This change was made in order to study the effect of concentrated superphosphate and muriate of potash at more rates of application.

The soil is a Dickson silt loam which occupies a considerable acreage in the Highland Rim section of Tennessee. One characteristic of this soil is a compact layer or fragipan at a depth of about 2 feet; it hinders water movement, making for a wet soil in the spring and a "droughty" soil in summer.

The area selected for the experiment had been in crop production for a number of years. Soil tests indicated a pH of about 5.6, a medium to high phosphorous level, but a very low to low level of potassium.

Yields of corn, wheat, and red clover obtained with CSP and ROCK in the first phase of the experiment are shown in Table 6. The performance of fused tricalcium phosphate, dropped from the experiment in 1955, will be discussed later. Since there was little or no consistent difference in the yields on the limed and unlimed sections, they have been combined and averaged.

CORN.—Corn yields fluctuated widely not only among phosphorus treatments in certain years but from year to year with a particular phosphorus treatment. For example, in 1950 the CSP treatments averaged over 100 bushels per acre, yet the yield was only about 65 bushels with ROCK. In the dry summer of 1952 the average yield for all phosphorus sources was only about 15 bushels. CSP was greatly superior to ROCK, yields averaging for the 6-year period about 52 bushels for CSP compared with about 39 bushels for ROCK. The higher rate of both sources resulted in only a slight improvement in yield over that obtained with the lower rate.

WHEAT.—Wheat yields also fluctuated, but less so than corn. The year 1951 produced the lowest yields (5 to 14 bushels), but yields approached 40 bushels with CSP in 1953 and 1954. As with corn, CSP was superior to ROCK throughout the period, yields averaging about 28 bushels for CSP compared to about 19 bushels for ROCK. The higher rate of both sources showed some improvement in yield over the lower rate.

RED CLOVER.—The performance of red clover was disappointing. Yields varied from fair to poor to crop failures. Growth was insufficient for harvest in 3 of the 7 years. Average yields for the 7-year period ranged from about ¾ to 1 ton of hay per acre. The crop failures are included in these averages.

Table 6.—Yields of corn, wheat, and red clover obtained with concentrated superphosphate (CSP) and rock phosphate (ROCK) in a 3-year rotation on Dickson silt loam (First phase, 1949-1955) (Average of 6 replications)

Source of phosphorus and pounds of P_2O_5 applied per acre for 3-year period	Year							Av.
	1949	1950	1951	1952	1953	1954	1955	
			CORN (bushels per acre)					
CSP, 60	75.3	101.3	56.1	17.1	37.6	23.0	....	51.7
CSP, 120	72.7	101.8	60.5	15.5	39.7	25.6	....	52.6
ROCK, 120	53.3	63.8	37.6	13.5	34.1	22.7	....	37.5
ROCK, 360	53.6	66.4	43.0	13.2	44.6	26.8	....	41.3
L. S. D. (5%)	7.3	15.9	6.1	N.S.	N.S.	N.S.	....	....
			WHEAT (bushels per acre)					
CSP, 60	18.6		12.0	30.7	37.1	39.0	....	27.5
CSP, 120	21.5	[1]	13.6	31.2	39.9	40.9	....	29.4
ROCK, 120	13.1		5.3	18.5	26.4	23.6	....	17.4
ROCK, 360	17.3		8.7	20.8	26.7	27.2	....	20.1
L. S. D. (5%)	5.6		1.7	5.2	2.5	5.1	....	....
			RED CLOVER HAY (tons per acre)					
CSP, 60		2.12	0.58		2.00		1.71	0.92
CSP, 120	Crop	2.24	0.64	Crop	2.12	Crop	1.96	0.99
ROCK, 120	fail-	2.06	0.40	fail-	1.52	fail-	1.31	0.76
ROCK, 360	ure	2.04	0.44	ure	1.75	ure	1.79	0.86
L. S. D. (5%)		N.D.	0.18		0.31		N.S.	....

[1] Harvested but ruined in the shock due to a prolonged rainy period.

FUSED TRICALCIUM PHOSPHATE.—The yields obtained with fused tricalcium phosphate in the first phase of this experiment were as follows:

Particle size and pounds of P_2O_5 applied per 3-year period	5-, 6-, and 7-year averages Corn	Wheat	Red clover hay
	Bu./A.	Bu./A.	Tons/A.
FTP, -10 mesh, 60	48.0	27.0	0.90
FTP, -10 mesh, 120	48.1	28.6	0.93
FTP, -40 mesh, 60	45.5	25.8	0.84

Comparing these yields with those shown in Table 6 it will be seen that the performance of FTP was slightly inferior to that of CSP but decidedly superior to that of ROCK. The poorer showing of the finer particle size (−40 mesh) of FTP is not understood. It would be expected that any difference in performance would be in favor of the finer particle size.

EXPERIMENT AT HIGHLAND RIM EXPERIMENT STATION, SPRINGFIELD—SECOND PHASE

As stated earlier, certain changes were made in the fertilizer treatments beginning with the wheat crop seeded in the fall of 1954. At this time ROCK at the 120-pound P_2O_5 rate and all FTP treatments were discontinued. This change was made to permit a study of CSP at more than two rates and of potassium at more than one rate.

The new fertilizer treatments applied to the corn and wheat crops, along with the former treatments, are shown in tables 7, 8, and 9, together with the yields of the three crops by years through the year 1960.

Corn yields for the 6-year period, 1955-1960, are presented in Table 7, it will be observed that average yields were much higher in this second phase than they were in the first phase (Table 6).[3] Moreover, corn production, which fluctuated so widely from one year to another during the first phase, was much more uniform during the second phase. How to explain this improvement in yield—whether to credit it as being due largely to better soil moisture relations, or to soil improvement or increased fertility—is difficult. However, the fact that the no-phosphorus treatments (treatments 1 and 2) produced much more corn in the second phase than did the rock phosphate treatment in the first phase would indicate that better moisture conditions is the more likely explanation. The soil moisture explanation also is supported by the better yields of red clover in the second phase (see Table 9).

CORN.—Summarizing treatments 1 to 12, corn yields for the various rates of phosphorus across all rates of potassium fertilization are as follows:

Phosphorus rate (Pounds of P_2O_5 per acre)	Bushels of corn per acre (6-year average, 1955-1960)
0	62.7
40	74.6
60	72.0
80	72.8

In like manner the yields for the various rates of potassium across all rates of phosphorus fertilization are:

Potassium rate (Pounds of K_2O per acre)	Bushels of corn per acre (6-year average, 1955-1960)
0	62.6
30	71.9
60	77.0
90	85.1*

* Not exactly comparable with the other rates of potassium.

It will be observed that an increase of about 12 bushels of corn was obtained from an application of 40 pounds of P_2O_5 but no

[3] Corn yields in both periods of this experiment were considerably higher than those obtained in a similar rotation experiment on the same soil type in Lawrence County, which was being conducted concurrently. The fertilizer treatment that produced an average of 66 bushels in this experiment produced only 41 bushels in the Lawrence County experiment (See Bulletin 328, "Phosphates in Crop Rotations in Lawrence County," published in 1961).

Table 7.—Yields of corn obtained with various phosphorus-potassium treatments in a 3-year rotation on Dickson silt loam (Second phase, 1955-1960) (Average of 3 replications)

Tmt. No.	Former treatment (Period 1949-1955)	Fertilization* (lb./acre)		Year						6-year av.
		P_2O_5	K_2O	1955	1956	1957	1958	1959	1960	
				Bushels per acre						
1	Rock, 120	0	0	54.9	53.5	71.0	53.6	61.9	61.1	59.3
2	Rock, 120	0	30	46.9	45.7	66.3	52.1	66.7	55.3	55.5
3	FTP, -10 mesh, 60	0	60	62.7	59.3	100.9	63.9	73.7	78.8	73.2
4	FTP, -10 mesh, 60	40	0	61.4	53.5	91.8	57.7	72.7	66.9	67.3
5	CSP, 120	40	30	69.0	61.8	87.7	78.7	76.2	88.8	77.0
6	CSP, 60	40	60	70.4	61.4	93.0	84.7	76.0	90.9	79.4
7	FTP, -40 mesh, 60	60	0	64.5	54.1	80.1	58.8	64.5	61.4	63.9
8	CSP, 120	60	30	68.1	54.8	93.5	75.4	71.6	88.9	75.4
9	CSP, 60	60	60	66.9	61.0	89.5	79.4	79.7	83.4	76.7
10	FTP, -40 mesh, 60	80	0	61.3	51.6	76.6	44.4	65.3	60.2	59.9
11	FTP, -10 mesh, 120	80	30	66.0	60.4	92.6	78.8	83.1	97.2	79.7
12	FTP, -10 mesh, 120	80	60	64.9	58.3	95.7	78.1	77.5	98.6	78.9
13	Rock, 360	360[1]	60	57.3	60.8	89.0	61.8	77.5	98.3	74.1
14	Rock, 360	**360[1]	60	58.6	62.4	79.0	70.5	85.9	91.0	74.6
15	CSP, 120[2]	60	90	71.4	63.3	107.8	92.4	80.7	105.8	86.9
16	CSP, 120[2]	80	90	69.4	62.6	101.6	92.2	79.9	94.6	83.4

* All treatments fertilized with neutralized ammonium nitrate. 65 pounds N per acre.

** Supplemented with CSP at rate 20 pounds of P_2O_5 per acre.

[1] ROCK applied only once in the rotation—before seeding wheat.

[2] These former treatments were the dolomitic limestone-unlimed pair in the first phase of this experiment.

Table 8.—Yields of wheat obtained with various phosphorus-potassium treatments in a 3-year rotation on Dickson silt loam (Second phase, 1955-1960) (Average of 3 replications)

Tmt. No.	Former treatment (Period 1948-1954)	Fertilization* (lb./acre)		Year						6-year av.
		P_2O_5	K_2O	1955	1956	1957	1958	1959	1960	
				Bushels per acre						
1	Rock, 120	0	0	14.0	31.4	5.9	15.0	13.1	13.6	15.5
2	Rock, 120	0	30	9.0	28.2	8.5	13.7	16.3	15.9	15.3
3	FTP, -10 mesh, 60	0	60	25.0	39.8	11.9	27.3	19.2	14.7	23.0
4	FTP, -10 mesh, 60	40	0	28.2	48.5	28.0	30.8	36.7	31.8	34.0
5	CSP, 120	40	30	32.8	51.1	29.2	34.5	36.4	31.6	35.9
6	CSP, 60	40	60	32.6	52.8	29.9	32.1	42.0	31.5	36.8
7	FTP, -40 mesh, 60	60	0	32.7	48.0	28.6	31.3	39.5	30.1	35.0
8	CSP, 120	60	30	36.0	60.6	35.5	42.0	43.0	35.9	42.2
9	CSP, 60	60	60	29.9	60.1	35.6	36.1	45.7	36.8	40.7
10	FTP, -40 mesh, 60	80	0	33.8	56.4	33.3	36.2	40.0	34.1	39.0
11	FTP, -10 mesh, 120	80	30	36.1	59.4	31.8	41.5	44.1	37.0	41.7
12	FTP, -10 mesh, 120	80	60	37.5	62.0	38.1	44.7	45.8	37.6	44.3
13	Rock, 360	360[1]	60	20.3	31.7	11.0	29.0	18.8	23.8	22.4
14	Rock, 360	**360[1]	60	25.8	47.0	24.5	33.1	33.3	31.0	32.5
15	CSP, 120[2]	60	90	36.0	55.0	34.9	40.0	44.6	34.9	40.9
16	CSP, 120[2]	80	90	34.6	58.7	40.9	40.3	43.4	39.3	42.9

* All treatments fertilized with neutralized ammonium nitrate at rate 60 pounds of N per acre, split 35 pounds at seeding and 25 pounds as topdressing in the spring.

** Supplemented with CSP at rate 20 pounds of P_2O_5 per acre.

[1] ROCK applied only once in the rotation—before seeding wheat.

[2] These former treatments were the dolomitic limestone-unlimed pair in the first phase of this experiment.

Table 9.—Yields of red clover obtained with various phosphorus-potassium rates applied to corn and wheat in a 3-year rotation on Dickson silt loam (Second phase, 1956-1959) (Average of 3 replications)

Tmt. No.	Former treatment (Period 1948-1955)	Fertilization* (lb./acre)		Year				4-year av.
		P_2O_5	K_2O	1956	1957	1958	1959	
				Tons hay per acre				
1	Rock, 120	0	0	1.60	1.68	2.05	0.84	1.54
2	Rock, 120	0	30	1.09	1.36	2.04	0.50	1.25
3	FTP, -10 mesh, 60	0	60	1.66	2.50	2.75	2.30	2.30
4	FTP, -10 mesh, 60	40	0	2.18	2.17	3.07	1.97	2.35
5	CSP, 120	40	30	2.18	3.24	3.11	1.69	2.56
6	CSP, 60	40	60	2.52	2.75	3.09	2.32	2.67
7	FTP, -40 mesh, 60	60	0	2.07	2.88	2.90	1.56	2.35
8	CSP, 120	60	30	2.19	2.67	3.47	1.63	2.49
9	CSP, 60	60	60	2.26	2.42	3.58	2.34	2.65
10	FTP, -40 mesh, 60	80	0	1.93	2.36	3.13	1.27	2.17
11	FTP, -10 mesh, 120	80	30	2.29	3.39	3.60	2.36	2.91
12	FTP, -10 mesh, 120	80	60	2.47	2.97	3.71	2.45	2.90
13	Rock, 360	360[1]	60	2.67	2.14	3.65	2.35	2.70
14	Rock, 360	**360[1]	60	2.38	1.99	3.64	1.72	2.43
15	CSP, 120[2]	60	90	2.71	3.96	3.81	3.16	3.41
16	CSP, 120[2]	80	90	2.77	3.41	3.76	2.96	3.23

* Applied to the corn and repeated on the wheat, the two crops that preceded red clover.

** Supplemented with CSP at rate 20 pounds of P_2O_5 to the corn crop and 20 pounds to the wheat crop.

[1] ROCK applied only once in the rotation—before seeding wheat.

[2] These former treatments were the dolomitic limestone-unlimed pair in the first phase of this experiment.

further increase in yield was obtained from rates higher than this.

The situation was quite different with potassium. An increase of about 9 bushels of corn was obtained from an application of 30 pounds of K_2O, but yields continued to improve with each increase in the rate of potassium. The average yield was 85.1 bushels at the 90-pound K_2O rate, and while this yield is not exactly comparable with the other rates, it indicates that 60 pounds of K_2O on this site was not enough for maximum yields of corn.

Of particular interest in this experiment is the increasing importance of potassium on corn over time. In the first phase potassium was not under study, it being applied at a rate of 50 pounds of K_2O per acre on all treatments. No potassium deficiency symptoms were noted during this period. However, when different rates of potassium were instituted in the second phase, the corn crop in several years showed pronounced potassium deficiency symptoms where potassium was discontinued. At the 30-pound K_2O rate deficiency symptoms were observable but they were not so pronounced. Thus, on this soil and with this cropping system, a change occurred from a situation in which phosphorus was the chief limiting factor in the first phase to one where potassium became the chief limiting factor in the second phase. Improved yields of red clover in the second phase undoubtedly contributed to the depletion of the soil's potassium reserves.

ROCK alone at the 360-pound P_2O_5 rate or ROCK supplemented with a small amount of CSP (treatments 13 and 14) produced yields comparable with those obtained with CSP.

WHEAT.—The wheat crop's response to fertilization was somewhat different from that of corn. Again, summarizing treatments 1 to 12 (Table 8), wheat yields for the various rates of phosphorus across all rates of potassium fertilization are as follows:

Phosphorus rate (Pounds of P_2O_5 per acre)	Bushels of wheat per acre (6-year average, 1955-1960)
0	17.9
40	35.6
60	39.3
80	41.6

In like manner the yields for the various rates of potassium across all rates of phosphorus fertilization are:

Potassium rate (Pounds of K_2O per acre)	Bushels of wheat per acre (6-year average, 1955-1960)
0	30.9
30	33.8
60	36.2
90	41.9*

* Not exactly comparable with the other rates of potassium.

Wheat, like corn, responded to both phosphorus and potassium. But wheat, unlike corn, continued to respond to phosphorus beyond the 40-pound P_2O_5 rate, although the responses to the second and third increments were not as pronounced as the response to the first increment.

Wheat also responded to potassium but the yield where no potassium was applied (30.9 bushels) was much higher than it was where no phosphorus was applied (17.9 bushels). The second and third increments of potassium resulted in about as much increase in yield as occurred with the first increment.

Rock phosphate (treatment 13) was decidedly inferior to concentrated superphosphate on wheat; in fact, the yield with ROCK alone was only about 5 bushels greater than the yield on the unphosphated treatments (treatments 1, 2, and 3). ROCK supplemented with a small amount of CSP (treatment 14) gave a much better performance. This improvement was probably due to the CSP.

Attention is called to the fact that wheat yields declined sharply beginning about 2 years after the phosphorus applications were discontinued, as illustrated in treatment 3. This treatment formerly had been fertilized with fused tricalcium phosphate but became a no-phosphorus treatment in the second phase. It declined to 11.9 bushels in 1957 and the yields thereafter were considerably lower than they were where phosphorus fertilization was continued. It is of interest to note that treatment 3 produced on the average about as much wheat as did the ROCK treatment (treatment 13), even though the rock applications were continued.

The difference in response of corn and wheat to fertilization illustrates two facts that have been observed in this and other experiments. The first one is that wheat requires a higher level of available soil phosphorus than does corn. Second, wheat will tolerate a much lower level of soil potassium than will corn.

RED CLOVER.—The red clover hay yields for the various fertilizer treatments during the second phase are shown in Table 9. It should be borne in mind that red clover was not fertilized directly; the fertilization as shown refers to what the corn and wheat crops received.

Summarizing treatments 1 to 12, the average yields of red clover hay for the various rates of phosphorus across all rates of potassium fertilization are as follows:

Phosphorus rate (Pounds of P_2O_5 per acre)	Tons of hay per acre (4-year average, 1956-1959)
0	1.70
40	2.52
60	2.50
80	2.66

The yields for the various rates of potassium across all rates of phosphorus fertilization are as follows:

Potassium rate (Pounds of K_2O per acre)	Tons of hay per acre (4-year average, 1956-1959)
0	2.10
30	2.30
60	2.63
90	3.32*

* Not exactly comparable with the other rates of potassium.

There were no crop failures in the second phase as was the case in the first phase. Moreover, the hay yields were much better in the second phase, indicating better soil moisture conditions.

The response to phosphorus was quite pronounced (slightly over ¾-ton of hay), but the response to potassium was even more pronounced. There was little or no increase in yield at rates higher than 40 pounds of P_2O_5 per acre, but yields continued to respond to the last increment of potassium (90 pounds of K_2O). At this 90-pound K_2O rate the yield was 3.32 tons of hay, an increase of 1.22 tons of hay (about 60%) over the no-potassium treatment.

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Highland Rim Forestry Field Station, Tullahoma
Milan Field Station, Milan

(3.5M/6-64)